International Journal of Disaster Risk Reduction 36 (2019) 101100

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Flooding in the James Bay region of Northern Ontario, Canada: Learning from traditional knowledge of Kashechewan First Nation

Muhammad-Arshad K. Khalafzai[a,*], Tara K. McGee[a], Brenda Parlee[b]

[a] Department of Earth and Atmospheric Sciences, 1-26 Earth Sciences Building, University of Alberta, Edmonton, Alberta, T6G 2E3, Canada
[b] Agricultural Life and Environmental Sciences, Resource Economics and Environmental Sociology, University of Alberta, 507 General Services Building, 9007 - 116 St NW, Edmonton, T6G 2H1, Alberta, Canada

ARTICLE INFO

Keywords:
Kashechewan First Nation
Indigenous Peoples
Canada
Participatory techniques
Traditional knowledge
Climate change

ABSTRACT

Traditional Knowledge has the potential to increase our understanding of many kinds of ecological phenomenon including floods. This article offers insights into the nature of spring flooding and its impacts in the southwestern James Bay region of northern Ontario, Canada from the perspectives of residents of Kashechewan First Nation. This article highlights the important contribution of Kashechewan First Nation's traditional knowledge to understanding and reducing disaster risks in this flood-prone region. Through a collaboration with Kashechewan First Nation, traditional knowledge was documented in 2016 during 17 in-depth interviews, participatory flood mapping workshops, on-site walks, and photography. The results of this study show that spring flooding has occurred seasonally over many generations in the region and has not increased significantly over time. However, the timing and extent of spring flooding has changed in recent years with warming temperatures in the region (i.e., earlier spring, snowmelt, and rapid runoff) and impacts are exacerbated by landscape and resource developments (e.g., inadequate infrastructure, substandard ring-shaped dyke wall, and downriver winter ice road) which have increased the frequency and scale of spring ice breakup and ice jams. These ecological changes have created the increased risk of flooding for the community of Kashechewan. The methodological approach which used participatory techniques may be useful for ongoing flood monitoring and disaster risk reduction activities in southwestern James Bay and elsewhere among the Canadian Indigenous communities.

1. Introduction

The risks of spring flooding in Canada's northern Indigenous communities have been a focus of both media and public attention over the last two decades. Although annual actual flooding or flooding risk and associated evacuations in the James Bay lowlands have been publicized, there is relatively little research on the spring flooding hazard risks. A critical gap within this literature is research that supports the oral histories and traditional knowledge (TK) of local First Nations communities. This article, based on collaborative research with the Kashechewan First Nation[1], aims to address this gap by exploring participants' (historical and contemporary) knowledge about spring flooding in their community. The research questions that guide this study are as follows:

1. What factors have elevated the spring flooding risk faced by the First Nation?
2. What are community members' flood-related observations on changes in the Albany River, in their landscape and the local environment?
3. How have Kashechewan First Nation coped with flooding hazard in the past and what is community members' perception of reducing the increased risk of flooding?

This article presents the results of research that used participatory methods of flood mapping, on-site walk, photography, and in-depth interview to investigate the regular spring flooding problem in Kashechewan. The study focuses on the elevated flood risk faced by residents since the establishment of Kashechewan in 1957. The most significant spring flooding occurred in the Albany River in 1966, 1972,

* Corresponding author.
E-mail addresses: khalafza@ualberta.ca (M.-A.K. Khalafzai), tmcgee@ualberta.ca (T.K. McGee), brenda.parlee@ualberta.ca (B. Parlee).
URLs: http://ualberta.ca (T.K. McGee), http://ualberta.ca (B. Parlee).

[1] Indigenous Peoples in Canada include Inuit, Metis, and First Nations. First Nations identify themselves by the nation to which they belong, e.g., Cree. https://www.aadnc-aandc.gc.ca/eng/1303134042666/1303134337338.

https://doi.org/10.1016/j.ijdrr.2019.101100
Received 7 June 2018; Received in revised form 7 February 2019; Accepted 20 February 2019
Available online 27 February 2019

1976, 1985 and 2006 [1,2]. Notably, Kashechewan residents have been evacuated 12 times because of actual flooding or flooding risks due to potential dyke failure since 2004. Although Indigenous Peoples have been adapting to gradual change for centuries, new global pressures are increasing their risks from environmental hazards while significantly changing their socio-economic, political, and environmental context in particular [3,4]. The study was completed in collaboration with the First Nation leaders and documented TK in November and December 2016 using culturally appropriate participatory techniques. In this article, we employ participatory methods which are a useful way for Indigenous communities to draw on their own conclusions for their problems in a strategy that works best for them [4,5].

TK is increasingly being recognized by academics, policy-makers, and managers, both in Canada and globally [6–11]. TK is contextualized as a body of cumulative knowledge, evolving by the adaptive process, passed on through generations, and associated with a specific place for a long time period [12–14]. TK has cultural and local meaning such as the Inuit way of doing things based on past, present and future knowledge and experiences of the Inuit People or the collective wisdom of Cree First Nations in Canada [14].

TK's contributions to understanding weather patterns, biophysical vulnerability, social-ecological resilience, and adaptation are well documented in many fields including natural resource management, environmental impact assessment, climate change adaptation, and natural hazards and disaster risk reduction (DRR) [15]. For example, TK of the Cree First Nations of Hudson Bay and James Bay contributed to the study that Ho, Tsuji, and Gough [16] conducted to determine river-ice breakup dates for the Albany, Moose, and Attawapiskat rivers. The study used the TK of Cree First Nations of the James Bay region because scientific data about the spring river-ice breakup had not been collected in recent years. TK can help researchers better understand Indigenous People's climate change observations, impacts, and opportunities for adaptation as well as vulnerabilities for DRR. The Intergovernmental Panel on Climate Change's (IPCC) 32nd Session also recognized TK as an important guiding principle for the Cancun Adaptation Framework (CAF), which was adopted by its members at the 2010 UNFCCC (United Nations Framework Convention on Climate Change) Conference in Cancun [17,18]. This framework highlights the contributions of TK to broader understandings of global climate change—including climate-change observations, impacts, and opportunities for adaptation and DRR. Furthermore, the UN agencies such as UNISDR have emphasized the need for mainstreaming and linking both DRR and climate change adaptation for future vulnerability reduction, particularly of communities at-risk of environmental hazards and climate change [19]. Additionally, climate change adaptation and DRR should be considered equally important because there exist more similarities than differences between the two [20].

TK offers valuable insights particularly into the areas of climate history, community adaptation, local scale expertise, and environmental monitoring in addition to a useful source of diachronic information on extreme events, subjective perspectives and qualitative data [21,22]. Diachronic information is based on observations of Indigenous Peoples on changes occurring in their environment over a period of time. Indigenous observations are based on smaller areas over a longer time period, which provides more opportunity to collect diachronic information; minimizing the chances of any change being overlooked. In essence, TK comprises the process of observing, discussing, and making sense of new information—in other words, Indigenous ways of knowing [23]. TK deals with a qualitative understanding of the whole system. Therefore, the diachronic information offered by TK can be a valuable resource, particularly when scientists are facing reduced funding for research. Collaboration with traditional knowledge-holders can help scientists recognize that Indigenous People's observations and assessments offer valuable insights to, and provide local verification of, e.g., global scientific models—; moreover, taking indigenous observations and assessments seriously can help experts ensure that adaptation measures align with local needs and priorities [24]. Such collaboration can also promote innovative and effective adaptation action, and relevant TK can inform cost-effective and sustainable DRR.

TK is an underutilized resource by the scientific community [25,26]. While TK is transmitted orally and lacks formal documentation, it is being eroded with the passage of time [27,28] because, for example, Kashechewan Elders (highly respected Indigenous historians and TK keepers) are passing away [29]; L. Friday, personal communication, November 16, 2016). Since TK system lacks formal documentation, DRR practitioners seem to be skeptical of the usefulness and potential contribution that TK can make in reducing hazards risks when dealing with disasters [27]. However, the benefits and contribution of TK within the DRR activities as well as harnessing its potential for implementation of sustainable development projects at the local level are now increasingly acknowledged and identified [3,30,101]. Exploring and documenting TK can also be a means to the participation and inclusion of people for integration of DRR into development for sustainability at the local level [3,28]. Through this research, learning from and documentation of Kashechewan First Nation's TK can contribute to the future DRR activities in the flood-prone southwestern James Bay region. Notably, one of the guiding planning principles of the Kashechewan First Nation and Ontario Provincial Government's Community-based Land Use Plan 2017 is that “planning decisions will be based on the best available data and information drawn from both Indigenous traditional knowledge and western science” [29]; p. 4).

Several studies have been conducted in flood-prone Canadian Indigenous communities from various perspectives including risk perception, preparedness, coping strategies, hydro-damming projects, livelihood sustainability, social learning, and climate change-related vulnerabilities and impacts. For example, Thompson, Ballard, and Martin [31] examined the artificially flooded and permanently displaced (development-induced displacement) Lake St. Martin First Nation in Manitoba because the provincial government decided to divert floodwater to the reserve to protect urban and agricultural properties. Their research methods included workshops on strategic analysis and community planning and participatory video component using the sustainable livelihood framework. Newton [32] examined flood risk perception and the community-level preparedness and coping strategies of northern Indigenous Peoples including Attawapiskat First Nation in the southwestern James Bay. He used the methods of mailed questionnaires, field observations, and qualitative interviews to collect data. Our study is different from others because it focuses on spring flood-related TK of the Kashechewan First Nation and their observations on the breakup ice jamming phenomenon in the midst of climate change and global warming.

Researchers are also increasingly using participatory techniques, for example, hazard mapping at the community level for DRR while researching with Indigenous Peoples [100,33,34]. This study employed multiple participatory techniques to collect data, which are culturally appropriate keeping in view the study objective and the theoretical framework. Participatory mapping and photography were used by Gill, Lantz, and GSCI [35] involving Teetł'it Gwich'in land users and youth from Fort McPherson, Northwest Territories, Canada to record information about local environmental conditions and changes. Their study used GPS (Global Positioning System) devices to record changes

Fig. 1. Study site map.

in the local environment. Mercer [20] used participatory techniques for mapping flood (open-water flooding), an active volcano, and landslides as well as the impacts of land-use practices and changes observed in their environments including land, rivers, and forests to identify the environmental impacts on the small Indigenous communities of Kumalu and Singas in Morobe and Madang Provinces of the small island developing states (SIDS). However, there are no TK studies on spring flooding in the James Bay region and a very few studies involving Kashechewan First Nation. Of the many TK studies elsewhere, this study is similar to others in terms of using the flood mapping method, which is considered a standard method for hazard mapping. However, this study is unique because it specifically focuses on the spring (i.e., breakup ice jams) flooding hazard, which is a different ecological phenomenon as compared to other types of floods (e.g., open-water or flash flooding). Spring floods have the greater potential for damage and are more dangerous than open-water floods. Other main differences include the use of multiple participatory techniques including an on-site walk and photography as well as flood mapping. This study's methodological approach was the first application of participatory techniques in the region and may be considered a useful method for flood monitoring and risk reduction by other First Nations communities at the risk of flooding in northern Canada. Notably, previous research has largely focused on the physical factors initiating the process of breakup ice jams that cause spring flooding. The focus of this study is on exploring and documenting the Cree traditional and local spatial knowledge and observations using multiple participatory techniques.

2. Setting

2.1. Socio-cultural context

The Kashechewan First Nation is located on the North Channel of the Albany River in the southwestern James Bay (called 'Wee-nee-peg-kook' in Cree) region of Ontario (see Fig. 1). In the low Cree Dialect, the name Kashechewan or Keeshechewan means "where the water flows fast." The topography of the area is mainly low-lying, with an insignificant variation in elevation [36]. The lowlands are the largest wetland region of Canada that extend inland 160–322 km [36,37]. The Albany is the second largest river (982-km-long) in Ontario. It consists of the three sub-rivers, the Mammamattawa, Ogoki, and Kengogami. Its Cree name is Chichewan meaning "several rivers form one that flows towards the ocean" [38]. The Albany flows from northwest to northeast Ontario, emptying into James Bay. Kashechewan is in Treaty 9, signed in 1905, and is one of the seven Cree First Nations of the Mushkegowuk Tribal Council. According to Chief Leo Friday, there are 2,000 band[2] members (L. Friday, personal communication, November 14, 2016). An isolated and remote community, Kashechewan is about 12 km upstream from James Bay and 12 km from the nearest community, Fort Albany, which is on the southern bank of the River's South Channel. Fort Albany is accessible to Kashechewan residents during winter via ice road and during other seasons via boat. The nearest major town, Moosonee, is 150 km away.

The Albany First Nation Reserve No. 67 was created in 1910 with 225 square kilometers of territory. The Reserve is shared by the Kashechewan and Fort Albany First Nations, which are Anglican and Catholic, respectively. In the 1950s, the two communities were divided along religious lines. The Fort Albany Chief and Council governed the two First Nations until 1974. Since 1974, the Kashechewan First Nation has had a separate chief and council. At its establishment in 1957, the Kashechewan First Nation wanted to set up its community at a higher ground on the reserve territory.[3] Instead, the federal government established Kashechewan at its existing location. The Kashechewan First Nation, however, claims that the federal government said it would not provide housing and infrastructure unless the First Nation set up the community on the appointed reserve territory (O. Wesley, personal communication, November 16, 2016; [39].

Kashechewan is located in the flood-prone southwestern James Bay area and is susceptible to spring flooding. In 1995–97, to protect the community, a ring-shaped 5.3-km-long and 3.5-m-high dyke wall was built at cost of $16.1 million using gravel and sand [39–41]. The dyke that surrounds the Kashechewan town is located along the riverside in the east and along the Red Willow Creek in the north and west, and at

[2] A "band" is a governing unit of Indigenous peoples in Canada.

[3] Standing Committee on Aboriginal Affairs and Northern Development [99]; p. 2). (http://cmte.parl.gc.ca/Content/HOC/Committee/381/AANO/Evidence/EV2067775/AANOEV48-E.PDF).

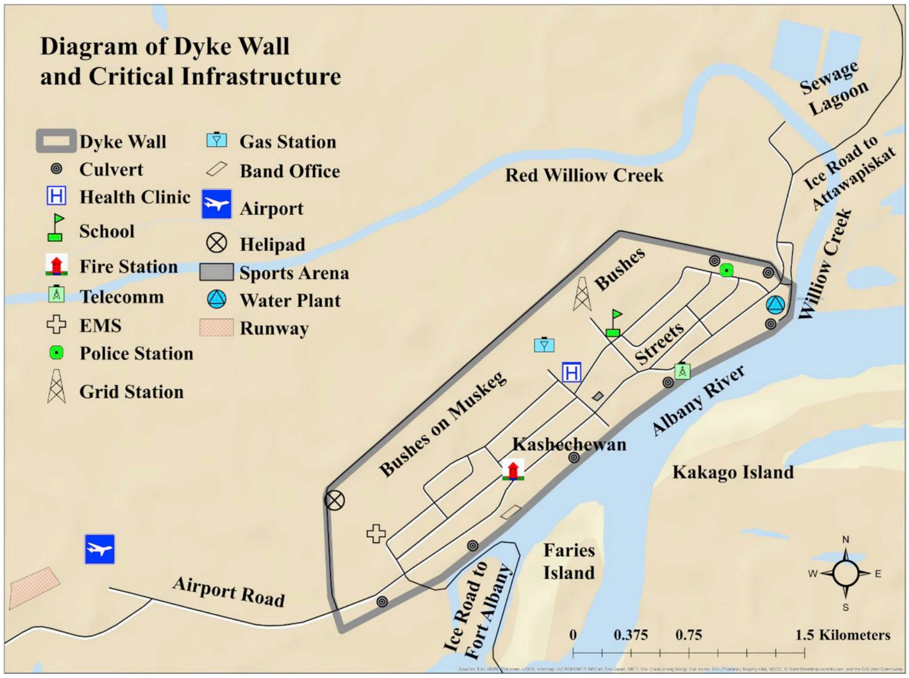

Fig. 2. Diagram of ring-shaped dyke wall and critical infrastructure.

Table 1
Past events of flood risk or actual flooding, E. Coli, and evacuations.

Event Type	Event Date	Community Affected	People Evacuated	CD$ Million	Host City/Community
Flood risk	26th April 2018	Kashechewan	1,690	–	Timmins, Kapuskasing, Cochrane, Smooth Rock Falls (SRF), and Thunder Bay.
Flood risk	16th April 2017	Kashechewan	600	–	Kapuskasing, SRF, and Hearst.
Flood risk	27th April 2016	Kashechewan	1,207	–	Kapuskasing and Thunder Bay.
Flood risk	17th April 2015	Kashechewan & Fort Albany	1,333	**9.4**	Kapuskasing, SRF, Wawa, and Cornwell.
Flood risk	April 2014	Kashechewan	1,600	**21.0**	Kapuskasing, Thunder Bay, Greenstone, and Cornwell.
Flood risk & sewer back-up	30th April 2013	Kashechewan	1,500	–	Kapuskasing, Kirk Lake, Englehart, Cochrane, Iroquois, North Bay, and Cornwell.
Flood risk	24th March 2012	Kashechewan & Fort Albany	269	**6.7**	Kapuskasing, Thunder Bay, and Wawa.
Flood risk	April 2007	Kashechewan	–	–	Stratford and Sudbury.
Flood risk	23rd April 2005	Kashechewan	200	–	Moosonee and Cochrane.
Flood risk	April 2004	Kashechewan	–	–	–
Flood risk	1st January 1989	Kashechewan, Fort Albany & Attawapiskat	1,000	–	–
Actual flooding	25th April 2008	Kashechewan & Fort Albany	1,900	–	Cochrane, Geraldton, and Sudbury.
Actual flooding	23rd April 2006	Kashechewan	1,100	**20.2**	Peterborough, S.S.Marie, Thunder Bay, Geraldton, and Cochrane.
Actual flooding	April 1985	Kashechewan	–	–	Moosonee.
Actual flooding	April 1976	Kashechewan	300	–	Fort Albany, and Moosonee.
E. Coli found in tap water	26th October 2005	Kashechewan	1,100	**16.00** 1.0 (plant)	Attawapiskat, Cochrane, Ottawa, Moosonee, Sudbury, and Timmins.

(Sources: W. Sutherland, personal communication, May 9, 2018 [43,45–47]; [2,48,49]. Note: The sign "—" indicates that information is not available from a reliable source.

the crossing of the airport road in the south as highlighted in Fig. 2. In 2006, flood waters rose and leaked through the dyke.[4] Studies showed that the construction was not "in accordance with the drawings and specifications," and as a result the dyke does not meet the required safety standards [42]; p. 8). In 2007, the federal government agreed to spend $200 million over five to seven years for community infrastructure including dyke improvements [43,44]. From 2006 to 2009 and in 2010, $3.5 million and $5.6 million were spent by the federal government to improve the dyke with concrete blocks to prevent it from eroding; erosion had been occurring at the rate of one foot per year because of heavy ice pushed towards the dyke [43]. The concrete blocks started displacing (see Photo 2) after the 2010 spring season, and the 2014 heavy ice jams severely damaged the dyke [40]. In 2015, the engineers commissioned by the First Nation reported that the dyke is deteriorating and inadequate to protect the community [43].

Since the establishment of Kashechewan in 1957, the most significant spring flooding occurred in 1966, 1972, 1976, 1985 and 2006 [1,2]. Kashechewan residents have been evacuated 12 times because of actual flooding or flooding risks since 2004 (see Table 1). The

[4] The dyke deficiencies could result in failure during flood/ice jam events.

government commissioned a study in the summer of 2006 to investigate the problem. The study recommended relocating the community to Timmins, 460 km to the southwest [39]. The community refused the government proposal because it wanted to relocate 30 km upriver on the reserve territory. In 2007, the government decided not to relocate the community because of the cost [44,50], which was estimated at $500 million (excluding non-financial, social and cultural costs) and increased to $750 million[5] [40,51]. As the relocation did not occur, the community continues to face elevated spring flood risks. After 2006, residents were evacuated because of actual flooding or flooding risks in 2007, 2008 and, then, every year between 2012 and 2018, all at significant costs. For example, during the 2014 flooding, $21 million was reportedly spent to evacuate the community.[6] In a referendum commissioned by the band in October 2016, 89% of band members voted in favor of relocating 30 km upriver, 3 km inland (L. Friday, personal communication, November 14, 2016).

2.2. Climate, river morphology and human ecology

The southwestern James Bay region is part of the Hudson Bay Lowland, one of the seven physiographic regions[7] of Canada [38]. The lowlands also are the largest wetland region of Canada, which remained covered by glaciers until about 10,000 years ago [36]. The James Bay waters significantly influence the region's weather, which comprises relatively cold and warm temperatures in summer and winter, respectively [37]. James Bay largely remains free of ice from mid-July to mid-October with little or no open water after mid-December [37]. The Kashechewan mean daily minimum temperatures in December, January, February, March, and April are −7, −23, −23, −15, and −6, and mean daily maximum during the same months are −9, −13, −11, −5, and 3 °C, respectively, with 200–240 cm mean annual snowfall [36]. The hot days in June, July and August are recorded 31, 32, and 31 °C, respectively. The average precipitation over 50 mm is between May and October, and 38 mm during April, which is the crucial month triggering spring flooding.[8]

The Albany River consists of multiple channels near its mouth at the bay. The North and South Channels split into two or more subchannels, which are narrower than their respective parent channels with almost the same slope; however, the river's slope flattens when it approaches the bay [52]. Numerous smaller connecting channels run in the north and south directions between the two parent channels [52]. While the flow distribution between both varies and is dependent upon the river's total discharge, the North Channel carries more flow than the South Channel [52]. There are several islands and rapids[9] in the two parent channels, which contribute to ice jams and trigger flooding. The Albany Island is the largest among all islands and divides the North and South Channels at the river's mouth. The downriver islands of Fafarid, Linklater, Kakago, and Faries in the North Channel, and Willow and Anderson in the South Channel can cause ice jams and therefore are considered dangerous. For example, Fafarid Island caused major ice jams, which triggered the flooding events of 1976 and 1985 [1].

Natural resources including wildlife and fish are crucial for Cree land-based sustenance economy. Spending time on the land and camping grounds and engaging in traditional hunting called “Bush Life” is considered essential by the community leaders for sustainable livelihood security and Cree social and cultural health [36]. Traditional hunting, trapping and fishing, and harvesting the hunted meat such as smoking geese contribute to the First Nation's food and nutrition requirements and is based on the region's wildlife. The community has abundant wildlife including geese, ducks, moose, beaver, bears, wolves, rabbit and otters. The abundant marine food sources are whitefish, trout, northern pike, pickerel, and sturgeon. The region's vegetation includes black spruce, sphagnum moss, and ground lichen in the bogs, and sedge, birch, and tamarack in the fens in addition to white spruce, balsam fir, trembling aspen, balsam poplar, and white birch, which occur in the better-drained areas [36]. The changing climate and unpredictable weather are affecting the pattern of migratory birds in the region, and the increased risk of flooding is negatively impacting spring hunting of the First Nation.

2.3. Spring flooding hazard

Many Canadian watersheds, including the Red River and the Albany River basins, are exposed to spring flooding—one of the foremost natural hazards among remote and isolated northern communities [1,53–56]. From 2006 to 2016, 67 First Nations experienced 100 recorded floods in Canada [57]. During the same period, 13 First Nations experienced 20% of the recorded floods alone in Ontario [57]. As the frequency and intensity of spring floods are expected to increase over time because of global warming, Indigenous Peoples are likely to be heavily affected [56,58,59].

Spring flooding occurs because of the temporary blockage of river flow and the build-up of broken-up ice blocks within a river channel. Jams cause the river water to rise instantly upstream, which may cause the river to overflow its banks, depending on the height of the blockage relative to the depth of the river [60]. The high flow, lower freeze-up conditions, and thin ice cover increase the probability of flooding [61–63]. Weather conditions such as temperature, wind speed, and precipitation also contribute to flooding because they affect the flow, and the ice-cover thickness and strength [62,64]. The flooding features, such as onset, speed, and magnitude, are governed by the region's topography, land-use pattern, vegetation and soil, and changes in the river in question [65]. Spring flooding has a greater potential for damage than open-water floods [59].

Ice breakup is “the period from when water levels begin to rapidly rise beneath ice cover, in response to the spring freshet, until ice is fully cleared from the river channel, typically just after peak water level” [66]; p. 12). The onset of breakup depends on water levels, freeze-up conditions, ice thickness and air temperature [64]. The two phases of ice breakup are premature and over-mature. The premature breakup involves rapid and extensive snowmelt, often augmented by rainfall, and is associated with rapid runoff [53]. The over-mature breakup is caused by mild weather with little or no runoff [53]. Premature breakup causes more severe flooding and damage than over-mature breakup [64]. The river slope, width, depth, and elevation also influence the breakup and flow pattern [63,64]. Climate-induced factors, such as the winter ice-cover thickness and river flow, affect the breakup and jam processes [62,64]. Ice breakup is more predictable than jams; the forecasting is essentially empirical as the site-specific local

[5] http://www.cbc.ca/news/canada/sudbury/kashechewan-prepares-for-another-flood-evacuation-worries-about-dike-1.3041852.

[6] http://news.nationalpost.com/news/canada/we-cannot-continue-to-live-this-way-flood-risk-forces-kashechewan-evacuation-for-fourth-year-in-a-row.

[7] The term physiographic means physical geography. The other six physiographic regions are Arctic Lands, Cordillera, Interior Plains, Canadian Shield Forest Lands, St Lawrence Lowlands and Appalachia. The divisions are based on each area's relatively similar physical geography and landforms (https://www.thecanadianencyclopedia.ca/article/physiographic-regions).

[8] https://www.meteoblue.com/en/weather/forecast/modelclimate/kashechewan_canada_5989520.

[9] Rapids are parts of a river where its bed has a relatively steep gradient or slope. They are hydrological features between a smooth flow and a cascade. Rapids can cause an increase in water velocity and turbulence.

conditions are not spatially transferable [59,67,68].

Ice jams are a vital feature of spring flooding faced by riverside communities, particularly in northern Canada [66,67,69]. A jam is defined as “a stationary accumulation of fragmented ice or frazil that restricts flow” [48]; p. 71). Jams are caused by surface ice blockage at floating obstacles, ice congestion at natural constrictions and reduced speed areas, and at typical jam geomorphic-related or manmade sites [48]. A sudden jam release threatens downriver communities because it releases large waves and ice-run [53,63,70]. Jams can occur within a few minutes, allowing very little time to evacuate [53]. They can be several meters thick and can increase the water level thrice as compared to the open-water flooding [53,64]. Jams are locally produced depending on site-specific geomorphologic conditions and are difficult to predict [59,62,64]. Ice jams are also influenced by factors such as hydraulic resistance, reduced flow velocity, curvature of islands, manmade obstructions, river confluence, and channel constrictions [48,63,64,71].

3. Approach and methods

A post-positivist approach guided this research because that approach challenges the traditional concepts of universal truth or presumptions about what constitutes a fact. When studying human perception, behavior, and action, post-positivism recognizes that researchers cannot be infallible about their claims of knowledge [72,73]. Post-positivists confront the positivist's notion of universal objectivity by challenging the dominant Eurocentric conceptions of social life to give voice to the marginalized (e.g., traditional knowledge-holders) who do not fit into the westernized mainstream social reality [74]. Hence, post-positivists proposed primarily a different conceptualization of truth [75]. Botha [76] argues that Indigenous research methodologies should go beyond conventional qualitative approach suggesting the mixed-methods research (MMR) using creative, participatory and reflexive techniques. He asserts combining existing qualitative methods with “the specific aspirations” of Indigenous Peoples in a “mixed method strategy framed within the cultural-historic activity theory (CHAT) principles of expansive learning” to reflect the distinctive epistemological aspects of the Indigenous ways of knowing [76]; p. 313). They are ‘Traditional Knowledge’ (handed down from previous generations), ‘Empirical Knowledge’ (gained through careful observations), and ‘Revealed Knowledge’ (spiritual in origin). This research employed MMR because combining qualitative and quantitative approaches, multiple methods, and sources of information offer a more in-depth understanding of a phenomenon and uncover different aspects of empirical reality [77–79]. The multi-method strategy attempts to serve the “particular theoretical, methodological and practical purposes” [77]; p. 182). MMR is more practical than a single method as it enabled using all required methods and multiple techniques to address the regular flooding problem in Kashechewan and allowed about 12% of the community members to participate in the research. The focus of this article is only on the qualitative research data and multiple methods used including in-depth interviews, flood mapping workshops, and on-site walks and photography activities. The results of this paper were developed using participatory techniques discussed later in this section. The quantitative results from the associated survey for assessing the adaptive capacity of the First Nation are presented elsewhere (thesis forthcoming).

The research project began with recognizing the important value of TK to understanding the ecological phenomenon of spring flooding and respect for the expertise of Elders within Kashechewan. The participatory techniques including flood mapping and qualitative interviews were developed to ensure that both narrative and spatial information could be documented. This study was collaborative in nature. It involved early input of the First Nation on the research proposal, respect for Cree traditions and differing perspectives, appropriate research objectives, recognition of various forms of knowledge systems, and seeking triangulation of information. The first author visited Kashechewan three times (2015, 2016, and 2018) in a 4-year period (2014–2018) and verified results with community leaders and Elders. The first author had the initial engagement with the community in November 2015 and spent a week in Kashechewan while presenting the research proposal to the Chief and Council and revised after receiving their input. This initial community engagement helped in building rapport and trust with the First Nation leadership, and understanding their priorities. After this initial visit, the first author spent five weeks in Kashechewan to collect data in October–December 2016, which further enabled building of rapport with other community members. Given that postsecondary enrollment of Indigenous Peoples in Canada is low, a young community research assistant (CRA) was hired and trained in the research methods to assist the fieldwork. Given that there has been little research carried out in Kashechewan, by working with a member of the community throughout the fieldwork, the researchers aimed to build capacity for the community to do its own research in the future.

During the third and visit for community reporting in November 2018, the first author presented ten large laminated posters containing quotes of Elders and the First Nation leaders, related additional information provided in plain language and photographs as a gesture of reciprocity while documenting Cree traditional and local spatial knowledge. The posters were presented to the community during an event held in the high school and displayed in the main hall of the school.

3.1. Participatory flood mapping

Participatory mapping is a process of map-making in which local people are asked to visualize their association with the land and environment by using language that is locally understood and accepted [80]. The purpose of mapping was to elicit TK and local spatial knowledge by facilitating discussion among the participants and availing the opportunity to build local capacity, give voice to TK holders, and facilitate two-way communication [81]. Participatory mapping also has been used to “investigate problem-oriented research questions” [33]; p. 233). In participatory mapping, the drawing sketch map technique is commonly used for DRR because it enables communities to delineate areas that they perceive to be prone and vulnerable to environmental hazards [82]. Cadag and Gaillard [82] call drawing sketch maps as the middle ground while comparing it with other mapping techniques such as on ground mapping and the technology-based GPS mapping. During the participatory mapping, participants drew sketches on unscaled and non-georeferenced google base maps provided by the band. In a group setting, participants identified the past flooded and high to low-risk areas, jam sites, and higher ground on the reserve.

The mapping technique was useful for identification of factors contributing to the hazard vulnerability of the community and allowed participants to share their knowledge of past and present flooding

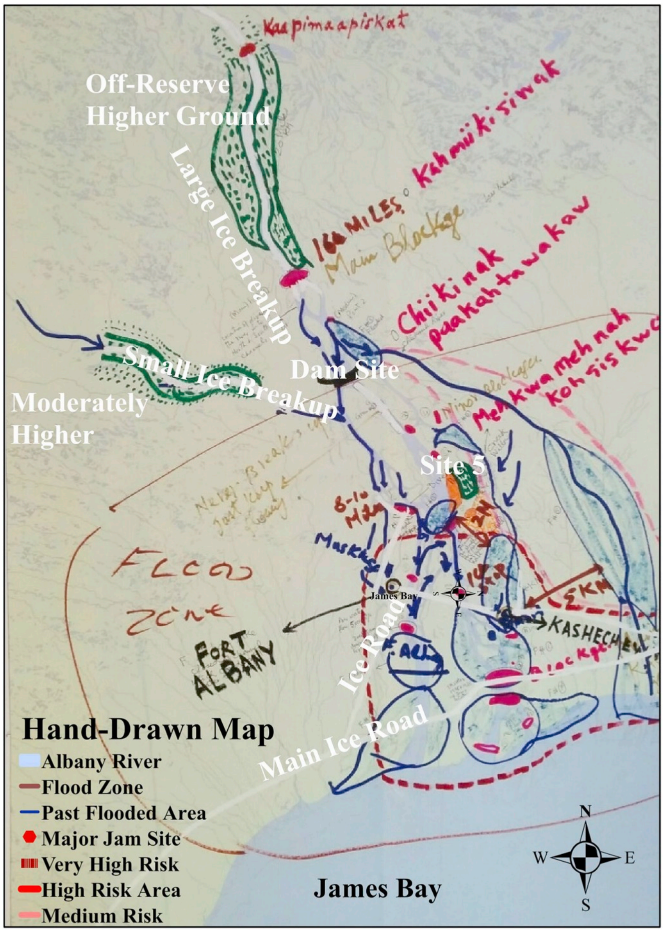

Fig. 3. Hand-drawn flood risk map.

events and localized flood characteristics while focusing on physical rather than socioeconomic aspects. The technique used was easily accessible to participants in the group setting. Experienced hunters, fishers, and trappers participated in the mapping workshops. It helped the authors to investigate the problem in a two-way rich social interaction by involving local residents as capable and active partners rather than passive recipients.

Five Elders participated in an hour and a half-long mapping workshops to draw sketches using the simple base map to indicate spring flood characteristics as shown in Fig. 3. The hand-drawn sketches were converted into Geographic Information System (GIS) using ArcMap software for accuracy. The sketch maps drawn on simple papers are rarely reproduced as standardized maps [33]. A participant who works as a Land-use Planner for the band provided suggestions to make the maps more precise using ArcMap, GIS. The results including maps were shared with and verified by the research participants for their input during the follow-up visit for community reporting in November 2018 and improved accordingly. The reproduced map (see Fig. 5) shows accurate distances between different locations, the elevation of the reserve territory, and the location of different sites, focusing in particular on breakup ice jam sites and the ice road.

3.2. On site walk and photography

The onsite walk technique is interactive, simple, and makes it inexpensive to gather information [83]. Photography also contributes to the process because it helps in documenting local spatial features and is now increasingly used while conducting research with Indigenous Peoples [35,84]. For example, photography of the floodwater height and dyke's vulnerable spots helped to document the fieldwork. Two knowledgeable Elders accompanied the first author on four separate walks (each about an hour long) to the dyke, and the areas around the airport, and the Albany River. The on-site walks helped provide detailed information about past flooded areas and details such as flood height, water inflow and outflow, and the raised platform of the helipad. The walks also helped the first author to understand the community's spatial context and to learn the river's morphologic features such as sharp bends and slopes. The walks contributed to the process of assessment of the community's physical vulnerability to floods. During the walks, critical sites were also photographed, including the low-lying areas, the dyke's vulnerable spots, and the floodwater height during past events in and around the community. Photography supplemented the on-site walks and flood mapping data and contributed to understanding the problem and documenting the local spatial knowledge. It also enabled this study to visually present the changes occurring in the local environment identified by participants (Photo 1).

Photo 1. The top photographs indicate the five-foot floodwater at the airport road indicated by Elder William Sutherland. The bottom photos show Elders (mapping participants) engaged in drawing sketches in the group setting.

3.3. Qualitative interviews

After the mapping exercise and on-site walks, the first author completed 17 semi-structured, in-depth interviews with Elders and community leaders who have extensive hunting, fishing, and trapping experiences. These interviews provided participants an opportunity to share their stories and experiences on changes observed in the river, on the land, and in their local environment. Qualitative interviewing is culturally appropriate when researching with Indigenous Peoples and respecting their traditions, customs and way of life [85]. The qualitative interviews allowed participants to share their narratives and experiences and present a more holistic picture of their understanding of the problem [77]. An interview guide of topics and questions, such as changes observed in the river's morphology, geographical and topographical changes since the establishment of Kashechewan in 1957, changes in the climate and its likely impacts on the breakup ice jamming phenomena, the winter ice road, and the muskeg wetland, was used to guide the interviews.

Before commencing interviews, the first author tested the guide by interviewing the community research assistant and revised it based on his feedback. The 17 interview participants were selected using the purposeful sampling technique. The criteria to select participants included community leaders and experienced hunters, trappers, and fishers who had been observing changes in their local environment as stated above. The average interview duration was a little over an hour. The qualitative interview method supplemented the participatory mapping techniques by enabling the first author to collect additional information in one-on-one conversations from all five mapping method participants in addition to 12 information-rich additional participants including women and community leaders such as Chief and Grand Chief who only participated in in-depth interviews. Collecting information using multiple methods and techniques from different participants helped the first author to understand the problem holistically.

The interviews recordings were transcribed by a professional transcriber. The transcribed data were coded and analyzed in the NVivo software while using a mix of descriptive (participants words) and analytical (literature reviewed) coding schemes [86]. During descriptive coding, the first author made categories using the local terms and words frequently and commonly used by the interview participants such as muskeg and wetland. The first author also derived (analytical) codes from the research literature, previous studies, and his understanding of the data. The data collected using other participatory techniques such as flood mapping and on-site walks were analyzed in the ArcMap, GIS and Google Earth software to produce scaled maps. For accuracy and precision, numerous shapefiles were used, which were available online. Several shapefiles not readily available online were also created by the first author to produce the maps. Photographs were analyzed by triangulating the information obtained from various methods and sources.

4. Results

4.1. Low-lying wetland

The region's topography is muskeg, marsh swamp, and wetland. Mostly, the reserve is low-lying and prone to spring flooding. The land is soft with a small variation in elevation. Mostly, the sea coastline (3–5 km inland) is tidal, mudflat, and below sea-level. Kashechewan is only a few feet higher than the river and 27 feet above sea level. The reserve territory's elevation decreases as it gets closer to James Bay and the land is less muskeg while moving away from the bay.

> *"For the longest time, this place hasn't been the best due to the lack of functional waterways. So, this place has been wet for way too long, and I don't like that".* (Kenneth Hughie)

According to mapping and interview participants, Kashechewan falls under the government declared flood zone. They also indicated that the relatively higher and safer ground (Site 5, which has about 24 m elevation) on the territory is 30 km upriver and about 3 km inland. Fig. 4 produced in GIS highlights the elevation of the study area, focusing on the reserve territory. While most of the reserve is at risk of flooding, Kashechewan is at "very high risk".

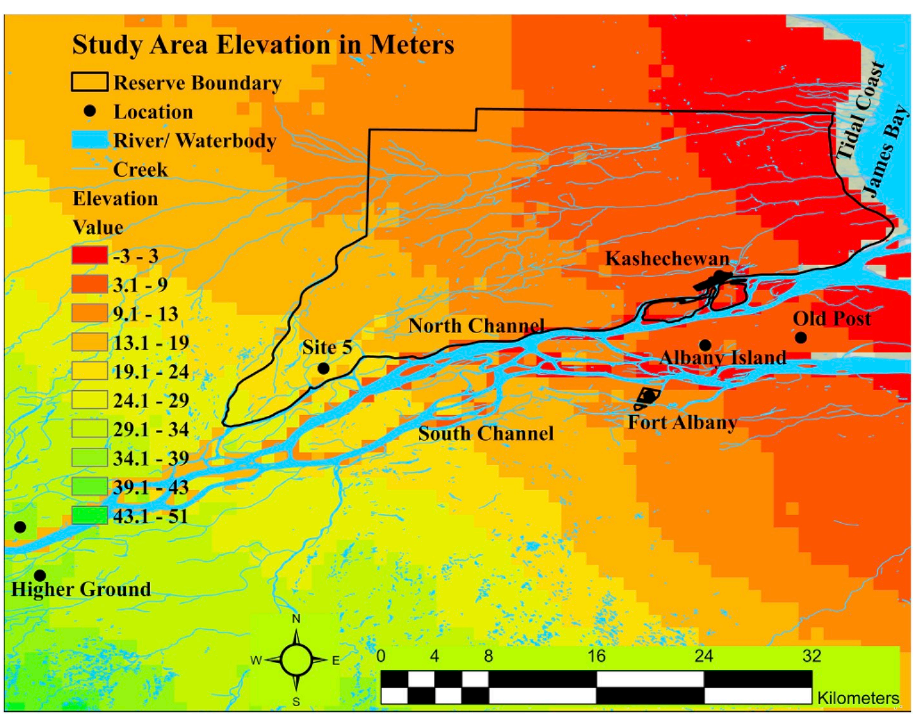

Fig. 4. Study area elevation map.

4.2. Community infrastructure

4.2.1. Ring-shaped dyke

Interview participants claimed that the government agreed to fulfill its treaty promises of providing additional housing, community infrastructure, and civic services only if the First Nation agreed to construct the dyke in the 1990s to protect the assets. As explained by one interview participant, the ring-shaped dyke was built in 1995–97. The dyke has several culverts, including five along the river with gates to control the floodwater outflow/inflow. According to this participant, engineers estimated the initial cost of a good quality dyke at $40 million, but a less expensive dyke was built for $16.1 million. Between 2006 and 2010 the federal government spent more than $9 million to improve the dyke after the relocation attempt failed.

> *"The government policy is a form of threat. Like you have no choice but to accept."* (Oliver Wesley)

Interview participants have many concerns about the dyke related to aesthetics, emotions, spiritual and physical needs, sociocultural issues, health, weather, safety, and trust. The 3.5-m-high dyke is bowl-shaped and surrounds the community from all sides while blocking views of the river and trees. As Tamara Koosees, an interview participant, said, "*It's ugly. It takes the beauty away from Kashechewan. The beauty is that river, and you can't see it unless you go up on the dyke. I don't like living in a bowl."*

> *"It's a very nice place to live with the river, the view. The one thing I don't like about since the change the dyke all around the community. It's because you can't see the trees the scenery has changed since that dyke, it's blocking the view. Before that, it was really nice."* (Valentino Kamalatisit)

One interview participant explained that the dyke obstructs her emotional and spiritual connection with the land and the river because it makes her feel disconnected from the natural environment.

> *"I don't like living inside the dyke. But other than that, I like [Kashechewan]. I love it. It feels like you're cut off from the land. It was way better when we were living without the dyke. Yeah, there's no sense, when [in the past] you look at the river, out in the bay, you sense this, just kind of peace, when you're looking out."* (Wilma Williams)

A participant who had been away from Kashechewan for several years said he used to see many canoes and people in the river and on the river bank before the dyke was constructed. He blames the dyke for keeping people away from the outdoors in this way. Another participant explained that the bowl-shaped dyke contains dust from unpaved dirt roads in the community, particularly during summer, which causes respiratory problems, especially among children because they spend a lot of time playing in the streets.

> *"The dyke causes a negative effect more because of the [dirt road] dust in the summertime. You drive around, you can't go nowhere. [Dust] goes within the dyke itself and cause[s] a lot of asthma [and] health issues."* (Edward Sutherland)

Two interview participants said that the community experiences higher temperatures and fewer fresh breezes in the summer because of the dyke. These environmental conditions stand in contrast to what occurs in the open environment outside the dyke. One participant also shared his memories before the dyke and its deteriorating condition.

> *"It seems like we're in a bowl here. You know, in the summertime, it's hot. I go over [walk on] the dyke. It's less hot on the dyke; the wind is not as lively [inside] as it is over the dyke. Growing up, my house was right by the river. I used to wake up in the morning and see a beautiful river. Now I don't see the river. I have to go on top of the dyke. But something that I observed is that it seems like the first year, the dyke was high, but it has settled; [it is] a little bit lower."* (Grand Chief Jonathan Solomon)

Although many participatory mapping and interview participants agree that the dyke protected the community, particularly from the 2006 flooding, they do not trust that the dyke, with its deficiencies, deterioration, and settlement, can save them from future flooding. Georgina Wynne said that the dyke has "*actually helped a lot of times,*" but that she fully expects, someday, "*it will just collapse on us 'cause it's been, like, over 10 years with that dyke. They [residents] say that it was higher, and it's going down, down, down, yeah."* Tamara Koosees agrees with Wynne and said that "*I don't feel safe because that bowl is not gonna last forever, and that's what it feels like. It's deteriorating, year by year, and it's not always gonna be there to protect us and it's gonna do damage."*

Another concern is that a large amount of snow inside the dyke can trigger non-riverine flooding during the spring breakup. The flooding can be triggered because of warmer weather, rapid snowmelt, the closure of culvert gates, and high flow in the river. The culvert gates are closed during the high spring river flow to prevent the floodwater coming through the culverts into the community. When the gates are closed the rapidly flowing snowmelt water is trapped inside the community, threatening Kashechewan with flooding. In spring 2014, the heavy river flow pushed the floodwater to leak through the culvert gates into the community, although the gates are meant to drain the snowmelt water from the community away, and into the river [40]. Participants explained that a breach of the dyke can inundate Kashechewan quickly, which will not give residents enough time to evacuate.

> *"It affects more after the dyke; people don't trust the dyke no more, even though it's there, saved the community twice, they [residents] still don't trust the dyke. If it breaks, it might flood the community in a couple of minutes […] plus [there is] no place to run, it's [area] all flat."* (William Sutherland)

> *"Well, definitely it would breach the dyke for sure, and also those culverts that shut. They're not that strong, yeah."* (Edward Sutherland)

During the freeze-up in winter and early spring, the dyke is strengthened as the ground and gravel freezes. The mild weather, however, thaws frost and can result in a breach. The dyke deficiencies and the 2006 floodwater leak add to the residents' uncertainty and fear. Grand Chief Jonathan Solomon quoted the late Cree Elder Francine J. Wesley, who used to say, "*we don't need to worry about the dyke because the dyke is frozen.*" Solomon wonders if the engineers considered the freeze-thaw cycle during the dyke testing. The Cree Elders knowledge of the dyke freeze-thaw cycle could have contributed to the findings of the study of engineers. The residents are more afraid of floating breakup ice than they are of floodwater, because if there is a sudden onset of flooding, they have little chance to evacuate using canoes. As Oliver Wesley said, "*even if you are in a canoe, ice will carry or destroy it. The flow of ice will carry the canoe away."*

The residents' fear of a dyke breach increased after the government said that shoring up the dyke for $40 million is still no guarantee that the community will be protected. Moreover, bad weather can potentially delay evacuation by air. The following pictures highlight the deficiencies and culverts and gates that can cause floodwater leakage into the community (Photo 2).

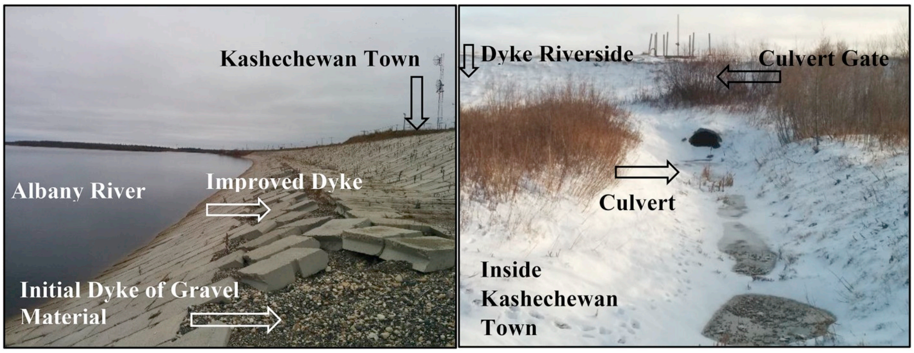

Photo 2. The deteriorating dyke and a culvert and its gate.

> *"It's on record by engineers saying that the dyke is high risk. […] You know, it's in a state of negligence. You know what is it gonna take to be heard [by the government]? A Disaster? I hope not."* (Grand Chief Jonathan Solomon)

4.2.2. Water treatment plant

Jams also affect the intake pipe of the conventional water treatment plant (see Photo 3). The plant is situated northeast of the town near the Red Willow Creek, and flows west to east into the river. The plant intake draws surface water from the creek. However, breakup ice affects the river water quality and blocks or damages the intake pipe and disrupts the drawing capacity for treatment and supply (see Photos 5 and 6).

Photo 3. Water treatment plant: Storage tanks and machinery/equipment.

In 2005, the breakup ice jammed the water intake pipe which forced the community to evacuate because *E. coli* was found in the treated water. The contamination occurred because of a drainage ditch upstream of the plant, and because the upstream sewage lagoon was clogged by a beaver dam. Meanwhile, excessive rain led to downstream water contamination. Mapping participants said that the sewage lagoon and drainage ditch located upstream of the plant are the potential sources of downstream contamination. In 2005, the plant operator also lacked adequate training [87]. That year, 1,100 residents were evacuated for about two months. In March 2016, 16 children were airlifted from Kashechewan after developing rashes and infections and the community reportedly blamed the plant for contamination [88]. Since the 2005 water contamination, many residents do not trust the tap water for drinking supplied by the plant. They buy bottled water from the Northern Store or the filtration plant operated by a local resident.

> *"Most people don't trust the water here 'cause that happened back then [2005]. […] So, they couldn't get water 'cause of the ice [that] was jammed in that intake, so our reservoirs [storage] kept getting lower, and [at] that point they had no choice [but] to shut down the pumps that runs the water to the community."* (Justin Wesley, Plant Operator)

4.3. Climate change

> *"The winters are getting milder; the winters are getting shorter. Climate change is not something that's gonna happen. It's happening it's been happening for a while now. Mother Nature is changing. They [Elders] observe[d] the winter. And they also observe[d] the temperature during the winter time, and how much snow. The less snow, the less blanket, so the frost goes deeper. The more snow, the frost is not as thick. So, they observe[d] these things, and they also looked at the muskeg how much water is out in the muskeg."* (Grand Chief Jonathan Solomon)

> *"The weather is getting warmer, the winter's getting shorter. Because, when I'm growing up, this time of year should be skidoo down the river, go to my camp. The river would be frozen by now [November]."* (Participant 10)

Participants say that winter used to be colder and longer and has now been reduced by up to two weeks, starting later in the third or fourth week of November, because of warming and late freeze-up. Participants explained that 15–20 years ago, snowfall would occur by mid- or sometimes early October and would be up to the knees by mid-November. That no longer happens. Fifteen to 20 years ago, by the end of October or early November, people would skate on the frozen river and go out to camps for hunting and to harvest[10] traditional food. For the past few decades, participants have been experiencing early spring and snowmelt. They explained that spring is two to three weeks shorter.

[10] Harvest refers to the hunting, fishing, trapping and gathering activities (Berkes et al., 1994).

Hunters used to go out hunting and would stay on their camping grounds until early June. Now, they are airlifted by the band using helicopters and return earlier in April because of the early breakup and flood risk. The hunting pattern has had to change because of warmer weather, which triggers an earlier spring breakup and has elevated the flooding risk. Hunters cannot stay longer on the land and return in mid-April because of the mandatory precautionary evacuation every spring. As Oliver Wesley said, "*there's hardly anybody that stay[s] in the bush for two months, they only stay, like a week or two.*" Edward Sutherland said that years ago, he used hunt until late April. "*Way back, we used to hunt late April. Now, the geese start arriving late March. It affects the hunting because of early spring, early warmth*".

In recent years, increased temperatures accompanied by excessive rainfall in the spring have caused a quick snowmelt. As a result, a large amount of water flows downriver. "*The increased flow has to do with snow lots of snow and warm weather and when it rains,*" said Oliver Wesley. "*That's what triggers lots of water.*" For example, excessive snowfall and a warm spell that remained for several days caused a major flood in 1976 in Kashechewan. The interview participants consider warming weather as the main cause of flooding. Heavy precipitation that continues for days also increases the probability of flooding. The participants' observations are consistent with the findings of Barnett, Adam, and Lettenmaier [89]; who reported that increasing temperatures cause earlier snowmelt in spring and affect the timing and volume of streamflow on the Canadian prairies. They argue that the accumulated snow and the spring melt phenomenon are more sensitive than precipitation to temperature.

One participant explained that Elders observe changes in the hydro-meteorological factors including accumulated snow (in the command and catchment area), ice thickness, and freeze-up conditions during winter, and river flow, temperature, and precipitation in spring. Their observations and forecasting the hydro-meteorological factors help them to determine the probability of a flood. Mapping participants also explained that the discharge threshold at the Hat Island gauging station (150 km upriver) is 5,000 m^3/s; that is the threshold that must be met in order for the band to declare an emergency in Kashechewan. One participant who has been Flood Watch Coordinator explained that the band started aerial monitoring of the river breakup ice jams after the 2006 flooding, and has not observed any significant change in the river flow during this period.

Unlike in the past, it is getting harder for participants to predict the weather. The unpredictability, for example, the sudden increase in temperature or heavy precipitation or a combination of both during the spring results in ice breakup and increases the flood risk, thereby forcing hunters to return to the community from their camps and hunting grounds.

> "*[The increased flow has] something to do with the water the break up why lots of water all of sudden when they [community] don't expect the high waters in the springtime. In the past, we never used to experience or heard of the flood before [1976] in this community. They [community] think it's something to do with climate change. […] You tend to see something is coming, and all of a sudden it's not, and sometimes you don't see something that's coming, and all of a sudden it is. That's how sneaky the weather is right now.*" (Chief Leo Friday)

One interview participant stated that the community is losing flood-related traditional knowledge. He explained that traditional flood preparedness practices such as preparing canoes with supplies and preparing a camp at a safer place for temporary relocation are disappearing because of reliance on the dyke.

> "*Sometimes I think we seem to put the traditional knowledge aside, but it is very important. Like, the observation that my grandfather used: traditional knowledge is something that's very valuable, even with climate change and how do you adapt to that? What we used to do prior to 1976 we used to get ready. I remember my grandfather, he would go up the airport road, and he used to build a pad over there [with] branches, trees up to five/six feet, and he would put a tent on top of that. So when the spring came, that's where he would go and live on top of that pad instead of staying here. You were more prepared. But I think, you know, okay, we got a dyke around us, we don't have to worry.*" (Grand Chief Jonathan Solomon)

4.4. Breakup ice jams

> "*They [Elders] observe the winter – how it was at this time of the year. If it's freezing over – did we have high water or was it low? And they also observe the temperature during the winter time, and how much snow. The less snow, the less blanket, so the frost goes deeper. The more snow, the frost doesn't – the ice is not as thick with – with less blanket of snow. So, they observe these things, you know, and they also looked at the muskeg – how much water is out in the muskeg.*" (Grand Chief Jonathan Solomon)

After the 2006 flooding and engineers' report about dyke deficiencies, as stated above, the band started monitoring the river breakup and jams using a helicopter. During the interviews, participants said that they had not observed any significant changes in the ice breakup phenomenon. However, the breakup events that occur at different locations in the Albany River system far upriver increase the risk of jams both up- and downriver. Participants say that the breakup process used to take longer because of colder weather and that in the past the water and ice flow continued without frequent jams.

> "*The spring breakups are almost the same every year but, sometimes [happen] more sooner now. [With] the slow breakup, we don't expect any flooding, because [ice] just moves, kilometre-by-kilometre. But the blockage is different where the ice jams up. Yeah, the regular breakup doesn't create any blockage. […] You [interviewer] have to be an "Indian" to understand [flooding].*" (William Sutherland)

> "*When there's breakup in those three [sub]rivers [Mammamattawa, Ogoki, and Kenogami] at the same time, that's a high risk of flooding. [If] it's only one breakup, and then another breakup comes, it's not noticeable, the ice is thinner. It's one at a time that's normal.*" (Oliver Wesley)

Participants explained that the warmer weather is causing more frequent jams, and the wet snow on ice contributes to jams.

> "*If [ice] breakup with snow in it, there will be ice jams because ice forms a wet snow they stick [together] because of wet snow.*" (Participant 10)

> "*See that curve there [four to five kilometers downriver]? That's where it jammed downstream when the 1976 flooding occurred. That's where it jammed, the ice, and that water built up it accumulated the water level, and that's how we got flooded because of the ice jam.*" (Oliver Wesley)

The research participants explained that predicting jams is difficult because a jam can occur anywhere in a river. There are, however, a few typical jam sites in the study area, particularly near the islands and the confluence point where the river divides into two channels. The jams include Kaapimaapiskat and the Fafarid Island located upriver near the confluence and downriver at the river's mouth, respectively (see Fig. 5 and Photos 4–6).

> "*Nobody knows where ice jams where it's gonna happen, but we know a few places that always happens, but no one is sure where [jams] gonna happen exactly.*" (William Sutherland)

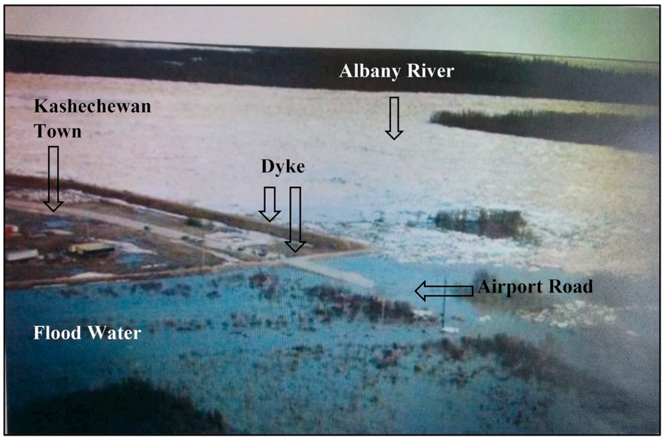

Photo 4. Spring 2006 flooding (source: Kashechewan band office).

Photo 5. The albany river spring breakup 2017 (photo: Holly Woodhouse).

The recent significant changes participants have observed include the more frequent occurrence of jams and increased number of jamming sites because of warmer weather. Warmer spring has also added to the jamming unpredictability.

4.5. Ice road

Interview participants explained that warming has reduced the span and safety of the 312-km-long winter ice road. The span of ice road was about three months during winter from January to March because the winter season used to be longer in the past. As a result, the ice road would open a few weeks earlier and would last longer. A participant who is an experienced ice road construction and maintenance worker said, "*the first time [16 March 2013] I experience[d] when the road was all gone, it was all melted*". He concluded that as a result of global warming access to the neighboring First Nations communities in the area is becoming restricted with the reduced safety level of the ice road (Photo 7).

Mapping and interview participants revealed that the ice bridges and ice ramps built for crossing the Albany River and creeks also cause jams.

> *"They [Winter Road Company] build ice bridges, ice crossing, and as they build [ice bridge], it causes a dam effect, [because] it dries up downstream, and floods upstream […] about 48 inches each year."* (Edward Sutherland)

> *"When they [Winter Road Company] built the ice bridge our river overflows because of the ice bridge. The river and creeks in our camping area overflows. […] One time we were almost flooded, near our campsite, where the chopper land, 100–150 yards away. The flood came this way. It never happened in the past." (Participant 9)*

The downriver ice bridge caused a jam and triggered the 2006 flood, incurring a cost of $20.2 million. Every spring, numerous holes are drilled in the six-to-seven-foot thick ice bridge to avoid jams. However, the freeze-up conditions block the holes and results in jams. "*The drilled holes don't help,*" said William Sutherland, "*and since then, we have problems with the flooding. That's where the ice stops downriver from Kashechewan and that's where it creates flooding.*"

4.6. Kashechewan-specific spring flooding characteristics

Fig. 5, produced in ArcMap (GIS), highlights the localized flooding features identified by participants based on their local spatial knowledge. The map focuses on breakup ice jams and higher ground on- and off-reserve territories. There are six major typical jams sites, shown as JM-1 to JM-6. The three downriver jams, JM-1 to JM-3, are critical and can cause the sudden onset of rapid flooding reaching several meters high, and leaving little or no time to evacuate. The jams JM-1 and JM-2, located four to 5 km downriver in the North Channel, seriously threaten Kashechewan. The jam JM-1, near Fafarid Island, caused the 1976 and 1985 floods. The jam JM-2 is at the river crossing and caused the 2006 flooding because the holes drilled in the six to seven feet thick ice bridge froze and blocked the flow. The increased flow caused by JM-2 in 2006 pushed the ice (two feet higher) on top of the dyke. Within a few hours, the airport runway (outside of the dyke wall) and its parallel road were inundated with two and five feet of floodwater, respectively. The entire community was evacuated by helicopters. The jam JM-3 in the South Channel causes flooding in Fort Albany and can also threaten Kashechewan by blocking and reversing the flow and then diverting it into the North Channel. The downriver jams are far more dangerous than the upriver jams; when the upriver jams occur, residents have several days to evacuate. The minor jams up- and downriver do not

Photo 6. The albany river spring breakup 2018 (photo: William Sutherland).

Photo 7. 312-KM ice road connecting First Nations of James Bay (source: http://www.winterroadcompany.ca).

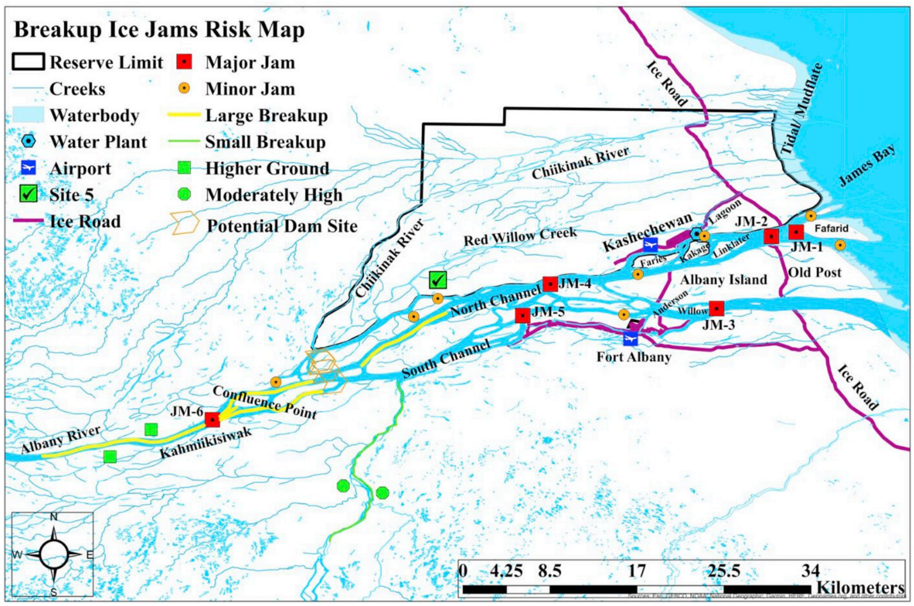

Fig. 5. Kashechewan-specific spring flooding risk map.

cause flooding. But they contribute to the major jam's flooding. Several islands and rapids in the two channels can cause jams and contribute to flooding. The downriver islands of Fafarid, Linklater, Kakago, and Faries in the North Channel, and Willow and Anderson in the South Channel contribute to the jams JM-1 and JM-2, and JM-3, respectively. The Albany Island causes the jam JM-3. The upriver islands near the confluence called Kahmiikisiwak cause the jam JM-6. Transportation and deposit of sand and sediments from up-to downriver around the islands and rapids also contribute to the jamming process. The off-reserve higher ground ('Kahmiikisiwak') has an elevation of 115–140 feet, which is over 100 feet higher than Kashechewan located about 55 km upriver. Another off-reserve relatively higher ground located about 40 km in the southwest of Kashechewan has an elevation of around 100 feet. Mapping participants explained that constructing a dam and moving the ice road upriver can prevent or mitigate jams.

4.7. Socio-economic implications

> *"We have to train our young people, but we don't have that anymore. Like, the harmony of the land, the importance of the land, the spiritual connection of the land, and those things that we have to teach our people, and especially preparing our meat. How to make it last long for the summer. That's we can't do that anymore. That's how much interference we have from the flood and the river system that we have, it's [getting] really hard."* (Chief Leo Friday)

Before the early 1920s, the Cree of the Hudson Bay and James Bay Lowland did not have permanent settlements and coped with floods by moving to higher ground in spring [2,32]. The permanent settlements increased their exposure to the flood risk. Interview participants claimed that their leaders agreed to relocate from Old Post, Albany Island to Kashechewan in 1957 to gain the treaty benefits that the federal government had promised along with the on-reserve resettlement. During interviews, the participants insisted that they must relocate but the government seems reluctant because of the high cost.

> *"But the reality is, someday it's gonna be flooding, that's why they [community] have to relocate, regardless. We need to convince the government that we need to relocate. It's just not pleasant to be in [Kashechewan] because you're displaced. You're just stressed out, and you can't enjoy life that's what it is. It [flooding] happened already a few times, and they [government] weren't convinced. I think they want us to die. You know what, that's in back of our mind, that's I think they're trying to, like, get rid of Indian problem. That stays in our mind that mentality still exists today."* (Oliver Wesley)

> *"The community is growing, and the government doesn't want to build more houses, and the people that are in the houses are overcrowded and I think it would be wiser to start thinking about the development of the new community and start implementing it."* (Chief Leo Friday)

"I'm hoping the government will give us new roads, a new water sewer system and new housing, new school, new hospital for our people. I know they spend millions and millions of dollars on evacuations, and if you add that up for a long time, it's cheaper for us to move upriver." (William Sutherland)

> *"I think relocation is not gonna happen tomorrow. It's gonna be years. It's gonna be a long process. The studies that need to be done, tendering, engineering, and everything. They're not gonna finish the whole process*

within three years. Let's not worry about the infrastructure, the housing they can be replaced but a loss of life cannot be replaced." (Grand Chief Jonathan Solomon)

In the October 2016 study commissioned by the First Nation, according to Chief Leo Friday, 89% band members voted in favor of relocation from Kashechewan to Site 5 because they do not want to lose their ancestral lands and natural resources.

5. Discussion

This study examined community members' flood-related traditional and local spatial knowledge using participatory techniques to investigate the regular spring flooding problem in Kashechewan. The study also explored how are spring flooding and its impacts on the local environment changing as a result of global warming and human-induced development in the region since the establishment of Kashechewan. Traditional knowledge and observations of research participants on changes in their environment helped in the in-depth understanding of the elevated risk of spring flooding. The timing and extent of spring flooding have changed in recent years with warming temperatures in the region and have caused earlier spring, snowmelt, and rapid runoff. The elevated risk of flooding has also exacerbated its impacts on Kashechewan residents especially because of inadequate community infrastructure, the substandard ring-shaped dyke wall, and the downriver ice bridge of the winter ice road, which, in turn, has increased the frequency and scale of spring breakup ice jams in the Albany River, without significant change in the annual average flow.

One of the findings is the increased ice jamming events and the increasing number of jamming sites with the warming temperatures in the region. Similar to participants' observations, the hunters and fishers of northern Canada have also observed 1–2 weeks late freeze-up in Fall and 1–2 weeks early Spring [16,90]. While the prediction of an ice jam is difficult, the Kashechewan Elders' ability to predict breakup ice jams due to increased warming temperature appears to have reduced. Participants' observations are also similar to those of Ho et al. [16] who noted potentially rapid changes in ice breakup in James Bay and predicted the earlier breakups and increased average temperatures in the region. McCarthy, Canziani, Leary, Dokken, and White [91] also predicted climate changes due to increasing temperature in the Hudson and James Bay Lowlands. The Albany River is also experiencing earlier breakup dates [16,92]. During three visits of Kashechewan in the month of November of 2015, 2016, and 2018, the first author also observed late freeze-up and experienced the first snowfall that occurred as late as mid-November, which would occur during October in the past as indicated by Kashechewan Elders. The first author also witnessed different species such as migratory birds and worms in mid-November, which would disappear as late as end October in the past as observed by the community Elders. It was also noted that the migration pattern of migratory birds is also being negatively affected. The change in the migration pattern of birds is impacting local hunting and traditional harvesting of meat. The earlier spring and elevated flooding risk have also negatively impacted the sociocultural activities of the community such as camping by hunters along with family including children on their traditional hunting and camping grounds. The reduced traditional spring hunting and camping in the bush is one of the main reasons for the erosion of traditional knowledge. With the significant reduction in spring hunting, the community Elders have now little opportunity to train their younger generation.

Human-induced development activities also appear to have aggravated the risk of spring flooding. It was noted that substandard dyke wall built improperly with gravel and sand material on peatland is the main cause of precautionary evacuation every spring, particularly after the 2006 flooding when floodwaters leaked through the dyke wall. The weak dyke foundation, which is only a meter deep without digging a core trench [93,94], does not allow raising or reinforcing the wall because it can not bear the additional load. The depression in the crest of the dyke, its erosion with the passage of time, and deficiencies reported by engineers [40,94] have resulted in the lack of trust of residents, which significantly adds to their psychological stress and anxiety as the spring season approaches. Raising the ground level within the dyke wall with a substantial cost can mitigate the urban (snowmelt within bowl-shaped dyke wall) flooding risk. However, this will not reduce the spring riverine flooding risk and other related problems of the First Nation because of the following reasons. Firstly, Kashechewan is at very high risk because of its flood-prone location and elevation, which is perhaps the lowest in the region. Based on their traditional and local spatial knowledge, the community Elders opposed the government's decision to establish Kashechewan in 1957 at its existing site. Secondly, the community has grown significantly from 300 band members in 1976 to over 2,000, therefore, requires additional space for new housing and community infrastructure while the existing area protected by the ring-shaped dyke wall (only 5.3 km long) is insufficient for the growing future needs. Thirdly, the emotional and psychological health of residents might remain in stressful condition because of experiences of the past flooding events, frequent evacuations, and the increased flood risk, particularly after the 2006 flooding, which was a close call. Lastly, based on their traditional knowledge, Kashechewan community Elders and leaders have concerns about climate change and its expected impacts on the First Nation and the neighboring communities of Fort Albany and Attawapiskat.

Another human-induced resource development activity relates to ice bridge of the winter ice road causing ice jams. For example, the ice bridge jamming caused the 2006 flooding. This result indicates that human disturbance of the local landscape as a result of infrastructural development can increase the risk of flooding. In fact, an ice bridge as a cause of ice jam flooding has not been indicated by previous research. The other related finding is the reduced time span and safety level of the 312 km long winter ice road, which connects the four First Nations communities of Moosonee, Fort Albany, Kashechewan, and Attawapiskat in the region. The ice road connects these communities during winter, therefore, has socioeconomic, communication, and transportation significance. The reduced span (about two weeks) and safety of the ice road because of earlier spring have significant implications for the Kashechewan First Nation. Particularly, the cost of essential food items and other goods is increased because they are transported by air during the off-season of the ice road. The air travel in the Canadian north including the James Bay region is expensive. The participants' observations about the impact of warming temperatures on winter ice road are consistent with those found in the literature. For example, the span of ice road shortened in northern Ontario during 1997–98 because of warmer weather, which has also delayed the road construction, particularly in muskeg areas [95–97]. In the past, the span was three months (January–March) because of long winter and would open a few weeks earlier and last longer [97]. To mitigate the flooding risk, building ice road upriver near the river confluence can prevent the ice bridge jamming. However, this may not be viable financially, technically, or because of increasing spring temperature. The higher spring flow due to breakup ice jams caused damage to the water treatment plant, coupled with the incidence of E. Coli in the tap water, resulting in the evacuation of residents at a significant cost. Hicks and Beltaos [59] also note that the excessive produced frazil ice can obstruct water intakes. The First Nation leaders consider the water treatment plant as an additional risk factor for their community. While visiting the plant, the first author observed that the plant appeared old, outdated, and is composed of obsolete technology.

Through structural and non-structural measures and technological mitigation strategies, spring ice jams risks can be reduced. Burrell [98] argues that the structural measures for jams prevention are reliable. However, they are too costly to be implemented and sustained because of capital and maintenance cost, particularly for a remote, isolated, and small Indigenous community. For example, construction of a dam

35–40 km upriver can prevent ice jams. The non-structural measures such as ice booms, ice blasting or cutting are cost-effective but are not reliable to protect lives and property. Other technological solutions such as piers and gates and ice control weir deployment upriver can mitigate ice jams but are not reliable. Based on their traditional and local spatial knowledge, the community Elders and First Nation leaders, however, consider such technological mitigation measures neither reliable nor sustainable to protect Kashechewan from the elevated risk of spring flooding in times of climate change and warming spring.

6. Conclusion

This paper focused on illuminating the observations and experiences of spring flooding based on the traditional and local spatial knowledge of residents of Kashechewan First Nation. The existing literature related to flood hazards in this region is relatively limited; previous research has highlighted aspects such as risk perception, emergency preparedness, health and livelihood, housing, social learning, and socioeconomic implications [2,40,57]; [32,43].

Participants identified a number of factors they feel have been exacerbated by climate change. These include the increased spring flows of the river, the increased temperatures, unpredictability of the weather, increased breakup ice jams events, and the reduced time span and the safety level of the winter ice road. Participants also identified the factors of low-lying and muskeg topography of the lowlands, and substandard community infrastructure; the deteriorating dyke wall and obsolete water treatment plant.

The results of this study highlight traditional and local spatial knowledge and indigenous observations of climate change impacts, including the typical breakup ice jams sites, which are lacking in the existing spring flooding literature. This research contributes to existing literature in three areas. First, the study documented the community's traditional and local spatial knowledge and their observations on changes in the spring flooding hazard. In particular, the timing and extent of spring flooding which have changed in recent years with warming temperatures in the region. Second, the study also explored the impacts caused by exacerbating factors of landscape and human-induced development which are equally contributing to the elevated risk of spring ice jams and resultant flooding. Third, as stated earlier, the methodological approach employed in this study was the first application of participatory techniques including flood mapping involving First Nation in the region and perhaps in Canada. Through the use of multiple culturally appropriate participatory techniques, the study brought new insight into how flood-related traditional and local spatial knowledge of the First Nation can be used to better understand localized flood risks and hazard-specific characteristics. In particular, we noted that the application of participatory flood mapping technique may be considered a useful method for ongoing flood monitoring and risk reduction for the study community and other Indigenous communities experiencing similar problems. The community's traditional and local spatial knowledge enabled this study to identify the main drivers of increased flooding risk and recurring evacuation every spring. Nevertheless, the findings of this research are not generalizable because they are Kashechewan context-based and spatial and temporal bound.

Lastly, this study also has identified areas for further research. There is a need to investigate the breakup ice jam phenomenon occurring in the South Channel of the Albany River that influences the flooding risk in Kashechewan while researching with the Fort Albany First Nation using flood mapping and other participatory techniques. Another area of collaboration for future research with Indigenous communities of the region is the reduced span and safety level of winter ice road because of warming temperatures using the mapping and other participatory techniques. Studying the impacts of increased flood risk and recurring evacuation every year on traditional hunting and harvesting during spring is also a potential area for research.

Acknowledgements

Special thanks to Kashechewan Chief Leo Friday, the Kashechewan First Nation and community leaders, all community members and to those who participated in the participatory flood mapping, on-site walks and photography, and the qualitative interviews. The Northern Scientific Training Program (NSTP) and U Alberta North, the University of Alberta, and Human Geography Program, Department of Earth and Atmospheric Sciences, the University of Alberta have provided the financial support for this research project. Dr. McGee, Tara and Dr. Parlee, Brenda provided much direction and guidance.

References

[1] R. Abdelnour, Albany River 2008 ice breakup: forecasting the flood event, observations of the river during the spring breakup and the potential for mitigating the flooding risk of the kashechewan and Fort Albany first nation. CGU-HS committee on river ice processes and the environment, 17th Workshop on River Ice Edmonton, Alberta July 21-24, 2013, 2013 http://cripe.ca/docs/proceedings/17/Abdelnour-2013.pdf.

[2] D. McCarthy, D. Crandall, G. Whitelaw, Z. General, L. Tsuji, A critical systems approach to social learning: building adaptive capacity in social, ecological, and epistemological (SES) systems, Ecol. Soc. 16 (3) (2011).

[3] J. Dekens, Local Knowledge for Disaster Preparedness: A Literature Review, International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal, 9789291150427, 2007https://www.preventionweb.net/publications/view/2693.

[4] J. Mercer, I. Kelman, L. Taranis, S. Suchet-Pearson, Framework for integrating indigenous and traditional knowledge for disaster risk reduction, Disasters 34 (1) (2010) 214–239, https://doi.org/10.1111/j.0361-3666.2009.01126.x.

[5] P.R. Louis, Can you hear us now? Voices from the margin: using indigenous methodologies in geographic research, Geogr. Res. 45 (2) (2007) 130–139, https://doi.org/10.1111/j.1745-5871.2007.00443.x.

[6] J.D. Gervais, Traditional Knowledge: A Challenge to Intellectual Property System, (2001) Retrieved on 3 February 2018, from http://discoverarchive.vanderbilt.edu.login.ezproxy.library.ualberta.ca/bitstream/handle/1803/5644/Traditional_Knowledge.pdf?sequence = 1&isAllowed = y.

[7] J.D. Gervais, Spiritual but not intellectual? The protection of scared intangible traditional knowledge, Cardozo J. Int. Comp. Law 11 (467) (2004).

[8] PRB (Parliamentary Research Branch), Indigenous Traditional Knowledge and Intellectual Property Rights, Library of Parliament, Political and Social Affairs Division, Canada, 2004 Retrieved on 8 February 2018, from https://lop.parl.ca/content/lop/researchpublications/prb0338-e.pdf.

[9] J. Anaya, Indigenous Peoples in International Law, Oxford University Press, New York, New York, USA, 1996.

[10] F. Mauro, D.P. Hardison, Traditional knowledge of indigenous and local communities: international debate and policy initiatives. Ecology applications, Ecol. Soc. Am. 10 (5) (2000) 1263–1269.

[11] WIPO, Roundtable on Intellectual Property and Indigenous Peoples. WIPO/INDIP/RT/98/1 Revised, World Intellectual Property Organization, Geneva, Switzerland, 1998.

[12] F. Berkes, Sacred Ecology: Traditional Ecological Knowledge and Management Systems, Taylor & Francis, Philadelphia, 1999.

[13] F. Berkes, J. Colding, C. Folke, Rediscovery of traditional ecological knowledge as adaptive management, Ecol. Appl. 10 (5) (2000) 1251–1262.

[14] D.G. Rosenberg, B.L. Hall, G.J.S. Dei, Indigenous Knowledges in Global Contexts: Multiple Readings of Our World, Dorothy Goldin Rosenberg, Pages Displayed by Permission of University of Toronto Press Incorporated 2000 Toronto Buffalo London Printed in Canada Reprinted 2008, (2000) 0-8020-4200-7.

[15] D.J. Nakashima, M.K. Galloway, H.D. Thulstrup, R.A. Castillo, J.T. Rubis, Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation, UNESCO and Darwin, UNU, Paris, 2012, p. 120 https://unesdoc.unesco.org/ark:/48223/pf0000216613.

[16] E. Ho, S.J.L. Tsuji, A.W. Gough, Trends in river-ice breakup data for the western James bay region of Canada, Polar Geogr. 29 (4) (2005) 291–299, https://doi.org/10.1080/789610144.

[17] Intergovernmental Panel on Climate Change (IPCC), Impacts on indigenous peoples: contribution of working group II chapter 16. Polar regions (arctic and antarctic) impacts, adaptation, and vulnerability in the third assessment report of the intergovernmental Panel on climate change, https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf, (2001).

[18] UNFCCC (United Nations Framework Convention on Climate Change), The Cancun agreements: outcome of the work of the AdHoc working group on long-term cooperative action under the convention, Report of the Conference of the Parties on its Sixteenth Session, Held in Cancun from 29 November to 10 December 2010, 2010 Retrieved on 20 September 2018, from https://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf FCCC/CP/2010/7/Add.1.

[19] F. Thomalla, T. Downing, E. Spanger-Siegfried, G. Han, J. Rockström, Reducing hazard vulnerability; towards a common approach between disaster risk reduction and climate change adaptation, Disasters 30 (1) (2006) 39–48.

[20] J. Mercer, Disaster risk reduction or climate change adaptation: are we inventing

the wheel, J. Int. Dev. 22 (2010) 247–264, https://doi.org/10.1002/jid.1677.
[21] H. Moller, F. Berkes, O.P. Lyver, M. Kislalioglu, Combining science and traditional ecological knowledge: monitoring populations for Co-management, Ecol. Soc. 9 (3) (2004) 2.
[22] D. Riedlinger, F. Berkes, Contributions of traditional knowledge to understanding climate change in the Canadian arctic, Polar Rec. 37 (203) (2001) 315–328.
[23] F. Berkes, Indigenous ways of knowing and the study of environmental change, J. Roy. Soc. N. Z. 39 (4) (2009) 151–156 1175-8899 (Online); 0303-6758 (Print)/ 09/3904-0151.
[24] United Nations University (UNU)., Seeing Traditional Technologies in a New Light: Using Traditional Approaches in Water Management in Drylands. United Nations University International Network on Water, Environment and Health (UNU-INWEH), A joint undertaking of UNESCO and UNV *(UNU-INWEH)*, 2009, pp. 12–14.
[25] A. Agrawal, Indigenous knowledge and the politics of classification, Int. Soc. Sci. J. 54 (173) (2002) 287–297 Retrieved on 15 September 2018, from https://doi-org.login.ezproxy.library.ualberta.ca/10.1111/1468-2451.00382.
[26] S. Twarog, P. Kapoor, Protecting and promoting traditional knowledge: systems, national experiences and international dimensions. New york and geneva, United Nations Conference on Trade and Development, 2004 https://unctad.org/en/docs/ditcted10_en.pdf.
[27] E. Dube, E. Munsaka, The contribution of indigenous knowledge to disaster risk reduction activities in Zimbabwe: a big call to practitioners, Jàmbá: J. Disaster Risk Stud. 10 (1) (2018) 493 https://DOI.org/10.4102/jamba.
[28] A. Rahman, Development of an integrated traditional and scientific knowledge base: a mechanism for accessing and documenting traditional knowledge for benefit sharing, sustainable socio-economic development and poverty alleviation, in: S. Twarog, P. Kapoor (Eds.), Protecting and Promoting Traditional Knowledge: Systems, National Experiences and International Dimensions, United Nations Conference on Trade and Development, New York and Geneva, 2004, https://unctad.org/en/docs/ditcted10_en.pdf.
[29] CBLUP, Community Based Land Use Planning: Terms of Reference. Kashechewan First Nation, Ontario Ministry of Natural Resources and Forestry, 2017 Rederived on 5 December 2018 from https://www.ontario.ca/page/kashechewan-first-nation-terms-reference.
[30] J. Mercer, D. Dominey-Howes, I. Kelman, K. Lloyd, The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states, Environ. Hazards 7 (2007) 245–256, https://doi.org/10.1016/j.envhaz.2006.11.001.
[31] S. Thompson, M. Ballard, D. Martin, Lake St. Martin first nation community members' experiences of induced displacement: "we're like refugees", Refugees 29 (2) (2014).
[32] J. Newton, An assessment of coping with environmental hazards in northern aboriginal communities, Can. Geogr./Le Geographe canadien 39 (2) (1995) 112–120.
[33] A.D. Smith, Participatory mapping of community lands and hunting yields among the bugle of western Panama. *Human organization*, Soc. Appl. Anthropol. 62 (4) (2003) 3323–3343 https://www.jstor.org/stable/44127814.
[34] J. Twigg, Disaster Risk Reduction: Mitigation and Preparedness in Development and Emergency Programming. Good Practice Review, No. 9, Humanitarian Practice Network, London, 2004.
[35] H. Gill, T. Lantz, GISCI (the Gwich'in Social and Cultural Institute), A community-based approach to mapping Gwich'in observations of environmental changes in the lower peel river watershed, NT, J. Ethnobiol. 34 (3) (2014) 294–314 https://doi.org/10.2993/0278-0771-34.3.294.
[36] K. Ohmagari, F. Berkes, Transmission of indigenous knowledge and bush skills among the western James bay Cree women of subarctic Canada, Hum. Ecol. 25 (2) (1997) 197–222.
[37] NAV-Canada, The weather of Ontario and quebec. Graphic area forecast 33, Retrieved on 12 September 2017, from http://www.navcanada.ca/EN/media/Publications/Local%20Area%20Weather%20Manuals/LAWM-Ontario-Quebec-EN.pdf (2002).
[38] Canadian Encyclopedia, Albany River, Retrieved on 15 September 2017, from, 2015. https://www.thecanadianencyclopedia.ca/en/article/albany-river.
[39] A.W. Pope, Report on the Kashechewan and its People. Alan W. Pope, Special Representative of the Minister of Indian and Northern Affairs, Canada, (2006) https://central.bac-lac.gc.ca/.item?id=kfnp_e&op=pdf&app=Library.
[40] S. Bhagwandass, Seeking higher ground: riparian vulnerability and the annual evacuations of kashechewan first nation, in: F. Gemenne, Zickgraf, D. Ionesco (Eds.), The State of Environmental Migration 2016: A Review of 2015, Presses Universitaries de Liege, 978-2-87562-117-7, 20166th Annual Volume.
[41] A. Shimo, My four months on a James bay reserve. Globe and mail, special to the globe and mail, (2017) Published on January 6, 2012 and updated on March 6, 2017. Retrieved On 15 March 2018, From https://www.theglobeandmail.com/news/national/my-four-months-on-a-james-bay-reserve/article1357793/ .
[42] R.C. Donnelly, D. Stephen, K. Jamieson, S. Perkins, S. Hinchberger, A Description of the Application of a New Quantitative Dam Safety Risk Assessment Tool for Risk-Informed Decision Making, (2015) Conference Paper Retrieved on 2 March 2018, from

https://www.researchgate.net/publication/279547123_A_Description_of_the_Application_of_a_New_Quantitative_Dam_Safety_Risk_Assessment_Tool_for_Risk-Informed_Decision_Making .
[43] A. Barei, Where the River Flows Fast. A Thesis Presented to the University of Waterloo in Fulfilment of the Thesis Requirement for the Degree of Master of Architecture Waterloo, Ontario, Canada, (2012) Retrieved on 15 January 2018, from https://uwspace-uwaterloo-ca.login.ezproxy.library.ualberta.ca/handle/10012/6459.
[44] C. Murdocca, "There is something in that water": race, nationalism, and legal violence, Law Soc. Inq. 35 (2) (2010) 369–402.
[45] Environment Canada, Evacuation exhaustion, Retrieved on 10 March 2018, from, 2008. https://ec.gc.ca/meteo-weather/default.asp?lang=En&n=F7C921B7-1.
[46] Environment Canada, Daily discharge data for Albany River near Hat island, Retrieved on 12 September 2017, from, 2017. https://wateroffice.ec.gc.ca/report/historical_e.html?stn=04HA001&mode=Table&type=h2oArc&results_type=historical&dataType=Daily&parameterType=Flow&year=2006&y1Max=1&y1Min=1.
[47] Public Safety Canada, Canadian disasters database, Retrieved on 20 August 2017, from, 2017. http://cdd.publicsafety.gc.ca/dtpg-eng.aspx?cultureCode=en-Ca&provinces=9&eventTypes=%27FL%27&eventStartDate=%2719570101%27%2c%2720181231%27&normalizedCostYear=1&dynamic=false&eventId=1085.
[48] S. Beltaos, River Ice Jams, Water Resources Publications, LLC, Highlands Ranch, Colorado, 1995, p. 372.
[49] Digital Journal, Kashechewan reserve may be facing another evacuation, Retrieved on 10 March 2018, from, 2007. http://www.digitaljournal.com/article/153246.
[50] A. Gosine, C. Teelucksingh, Environmental Justice and Racism in Canada: an Introduction, Emond Montgomery Publications Limited, Toronto, ON, 2008.
[51] K. Harries, Crees flown out as Albany River rises, The Indian Country Retrieved on 5 March 2016, from, 2008. https://indiancountrymedianetwork.com/news/crees-flown-out-as-albany-river-rises/.
[52] P. Grover, C. Vrkljan, S. Beltaos, D. Andres, Prediction of ice jam water levels in a multi-channel river: Fort Albany, Ontario, Proc. Tenth Workshop on River Ice, Winnipeg, Canada, Canadian Geophysical Union, 1999, pp. 15–29 Committee on River Ice Processes and Environment, Hydrology Section.
[53] S. Beltaos, river ice breakup processes: recent advances and future directions, Can. J. Civ. Eng. 34 (2007) 703–716, https://doi.org/10.1139/L06-021.
[54] A. Boluwade, F.P. Rasmussen, Frequency of floods in a changing climate: a case study from the Red River in Manitoba, Canada, Proc. IAHS 37 (2015) 83–88.
[55] M.J. Cunderlik, J.M.B.T. Ouarda, Trends in the timing and magnitude of floods in Canada, J. Hydrol. 375 (2009) 471–480.
[56] J. Newton, D.C. Paci, A. Ogden, Climate change and natural hazards in northern Canada: integrating indigenous perspectives with government policy, Mitig. Adapt. Strategies Glob. Change 10 (2005) 541–571.
[57] K. McNeill, A. Binns, A. Singh, Flood history analysis and socioeconomic implications of flooding for indigenous Canadian communities. The Canadian society for bioengineering, Paper No. CSBE17137 Written for Presentation at the CSBE/SCGAB 2017 Annual Conference Canada Inns Polo Park, Winnipeg, MB 6-10 August 2017, 2017 http://www.csbe-scgab.ca/docs/meetings/2017/CSBE17137.pdf.
[58] D. Green, G. Raygorodetsky, Indigenous knowledge of a changing climate, Clim. Change 100 (2) (2010) 239–242.
[59] F. Hicks, S. Beltaos, river ice, in: M. Woo (Ed.), Cold Region Atmospheric and Hydrologic Studies, Springer-Verlag Berlin Heidelberg, New York, 2008978-540-73935-7.
[60] G.R. Brooks, S.G. Evans, J.J. Clague, A synthesis of natural geological hazards in Canada: environment and climate change; flooding, in: G.R. Brooks (Ed.), 548 Canada, Ottawa, 2001, pp. 101–143 Geol. Surv. Can. Bull..
[61] S. Beltaos, Effects of climate on river ice jams, Proceedings of the 9th Workshop on River Ice, 24–26 September 1997, Fredericton, N.B. Committee on River Ice Processes and the Environment, Hydrology Section, Canadian Geophysical Union, Sidney, B.C, 1997, pp. 225–244.
[62] S. Beltaos, C.B. Burrel, Climate change and river ice breakup, Can. J. Civ. Eng. 30 (2003) 145–155, https://doi.org/10.1139/L02-042.
[63] S. Beltaos, T. Carter, Field studies of ice breakup and jamming in lower peace river, Canada, Cold Reg. Sci. Technol. 56 (2009) 102–114.
[64] S. Beltaos, D.T. Prowse, Climate impacts on extreme ice-jam events in Canadian rivers, Hydrol. Sci. J. 46 (1) (2001) 157–181, https://doi.org/10.1080/02626660109492807.
[65] R. Few, Flooding, vulnerability and coping strategies: local response to a global threat, Prog. Dev. Stud. 3 (1) (2003) 43–58.
[66] A.C. Emmerton, W.F.L. Lesack, P. Marsh, Lake abundance, potential water storage, and habitat distribution in the mackenzie river delta, western Canadian arctic, Water Resour. Res. 43 (2007), https://doi.org/10.1029/2006WR005139.
[67] L.R. Gerard, S.K. Davar, Occurrence of ice jams in Canada, in: S. Beltaos (Ed.), River Ice James, *Water Resources Publications*, Highlands Ranch, Colorado 80163-0026, USA, 1995, pp. 1–27.
[68] T.D. Prowse, river ice processes, in: S. Beltaos (Ed.), River Ice Jams, *Water Resources Publications*, Highlands Ranch, Colorado, USA, 1995, pp. 29–70.
[69] M. Woo, R.W. Rouse, E.R. Stewart, M.R.J. Stone, The mackenzie GEWEX study: a contribution to the cold region atmospheric and hydrologic sciences, in: M. Woo (Ed.), Cold Region Atmospheric and Hydrologic Studies, Springer-Verlag Berlin Heidelberg, New York, 2008978-540-73935-7.
[70] J. Nafziger, Y. She, F. Hicks, Celerities of waves and ice runs from ice jam releases, Cold Reg. Sci. Technol. 23 (2016) 71–80.
[71] R. Ettema, M. Muste, A. Kruger, Ice Jams in River Confluences. Cold Regions Research & Engineering Laboratory, CRREL Report 99-6, US Army of Corps of Engineers, 1999.
[72] J.W. Creswell, Research Design: Qualitative, Quantitative, and Mixed Approaches, Sage, Thousand Oaks, CA, 2003.
[73] D.C. Phillips, C.N. Burbules, Post-positivism and Educational Research. Philosophy, Theory, and Education Research Series, Rowman & Littlefield

Publishers, Inc., 0-8476-9122-5, 2000.
[74] I. Hay, Qualitative Research Methods in Human Geography, third ed., Oxford University Press, Oxford, UK, 2010.
[75] M.A. Clark, The qualitative-quantitative debate: moving from positivism and confrontation to post-positivism and reconciliation, J. Adv. Nurs. 27 (1998) 1242–1249.
[76] L. Botha, Mixing methods as a process towards indigenous methodologies, Int. J. Soc. Res. Methodol. 14 (4) (2011) 313–325.
[77] J. Brannen, Mixing methods: the entry of qualitative and quantitative approaches into the research process, Int. J. Soc. Res. Methodol. 8 (3) (2007) 173–184, https://doi.org/10.1080/13645570500154642 ..
[78] J.W. Creswell, V.L. Plano-Clark, Designing and Conducting Mixed Methods Research, second ed., Sage Publications Inc, Thousand Oaks, CA, 2011.
[79] N.K. Denzin, The Research Act: A Theoretical Introduction to Sociological Methods, McGraw-Hill, New York, 1978.
[80] IFAD (International Fund for Agricultural Development), Good Practices in Participatory Mapping, (2009) Retrieved on 20 August 2017, from https://www.ifad.org/documents/10180/d1383979-4976-4c8e-ba5d-53419e37cbcc.
[81] M. Chapin, Z. Lamb, B. Therlkeld, Mapping indigenous lands, Annu. Rev. Anthropol. 34 (2005) 619–638, https://doi.org/10.1146/34.081804.120429.
[82] D.R.J. Cadag, C.J. Gaillard, Integrating knowledge and actions in disaster risk reduction: the contribution of participatory mapping, Roy. Geogr. Soc. Area 44 (1) (2012) 100–109 1111/j.1475-4762.2011.01065.x.
[83] NOAA (National Oceanic and Atmospheric Administration), Stakeholder Engagement Strategies for Participatory Mapping. Social Science Tools for Coastal Programs, (2015) www.csc.noaa.gov.
[84] S. Samaddar, R. Chatterjee, A.B. Misra, H. Tatano, Participatory Risk Mapping for Identifying Spatial Risks in Flood Prone Slum Areas, Mumbai. Annuals of Disasters, Prev. Res. Inst., Kyoto University, 2011 No. 54 B.
[85] A.K. Kariippanon, K. Senior, Engaging and Qualitative Interviewing: an Ethnographic Study of the Use of Social Media and Mobile Phones Among Remote Indigenous Youth, SAGE Research Methods Cases, 2017, pp. 1–15.
[86] G.R. Gibbs, Analyzing Qualitative Data, SAGE, Thousand Oaks, 2007.
[87] B. Jacobs, Environmental Racism on Indigenous Lands and Territories, Report Published by Published by the Canadian Political Science Association, Canadian Race Relations Foundation (CRRF), 2010 Retrieved on 7 September 2017, from http://www.crrf-fcrr.ca/en/clearinghouse-search/7-clearingjouse-reserches-bibliographiques/rpt/417-environmental-racism-on-indigenous-lands-and-territories.
[88] HuffPost, Kashechewan First Nation's Children at Front and Centre of Recurrent Crisis, (2016) Retrieved on 7 August 2017, from https://www.huffingtonpost.ca/2016/03/23/kashechewan-children-skin-rashes-lesions_n_9534604.html.
[89] P.T. Barnett, C.J. Adam, P.D. Lettenmaier, Potential impacts of a warming climate on water availability in snow-dominated regions, Nature 438 (17) (2005), https://doi.org/10.1038/nature04141.
[90] J. McBeath, E.C. Shepro, The effects of environmental change on an arctic native community, Am. Indian Q. 31 (1) (2007) 44–65.
[91] J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken, K.S. White, Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution Of Working Group II to the Third Assessment Report Of the Intergovernmental Panel On Climate Change, Cambridge University Press, New York, NY, 2001.
[92] S.A. Gagnon, A.W. Gough, Trends in the dates of ice freeze-up and breakup over Hudson bay, Canada, Arctic 58 (4) (2005) 370–382.
[93] Hatch Ltd, Kashechewan First Nation. Assessment of Dam Safety Risks and Dam Safety Management Requirements for the Kashechewan Ring Dyke, (2015) Retrieved on 12 February 2018, from https://www.hatch.com/en/Projects/Energy/Kashechewan-First-Nation-flood-risk-forecasting-and-mitigation.
[94] C. Kauppi, H. Pallard, E. Faries, Poverty, Homelessness and Migration in Northeastern Ontario, Canada. International Journal of Sustainable Development, Ontario, International Development Agency, Canada, 2015 (print) ISSN 1923-6662. Retrieved on 6 February 2018, from 1923–6654, http://www.ssrn.com/link/OIDA-Intl-Journal-Sustainable-Dev.html.
[95] D.J. Ford, B. Smit, A framework for assessing the vulnerability of communities in the Canadian arctic to risks associated with climate change, Arctic 57 (4) (2004) 389–400.
[96] Y. Hori, Impact of Climate Change on Winter Road Systems in Ontario's Far North: First Nations' and Climatological Perspectives on the Changing Viability and Longevity of Winter Roads, A PhD Thesis Submitted to Department of Physical and Environmental Sciences University of Toronto, 2016 Retrieved on 20 January 2018, from https://www.researchgate.net/publication/318883948_Implication_of_climate_change_on_winter_road_systems_in_the_Far_North_of_Ontario_First_Nations%27_and_climatological_perspectives_on_changing_the_viability_and_longevity_of_winter_roads.
[97] Y. Hori, A.W. Gough, K. Butler, S.J.L. Tsuji, Trends in the seasonal length and opening dates of a winter road in the western James bay region, Ontario, Canada, Theor. Appl. Climatol. 129 (2017) 1309–1320, https://doi.org/10.1007/s00704-016-1855-1.
[98] C.B. Burrell, Ice jams prevention and mitigation, in: S. Beltaos (Ed.), River Ice Jams, Water Resource Publication, Highlands Ranch, Colorado, USA, 19951995.
[99] Standing committee on AAND (aboriginal Affairs and northern development), Retrieved on 10 October 2017, from, 2005. http://www.ourcommons.ca/en/parliamentary-business.
[100] C. Benson, J. Twigg, T. Rossetto, Tools for Mainstreaming Disaster Risk Reduction: Guidance Notes for Development Organizations, ProVention Consortium, Geneva, Switzerland, 2007https://www.preventionweb.net/publications/view/1066.
[101] S. Twarog, Preserving, protecting, and promoting traditional knowledge: national actions and international dimensions, in: S. Twarog, P. Kapoor (Eds.), Protecting and Promoting Traditional Knowledge: Systems, National Experiences and International Dimensions, United Nations Conference on Trade and Development, New York and Geneva, 2004, https://unctad.org/en/docs/ditcted10_en.pdf.